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ABSTRACT

This paper describes a joint research project between science educators and computer science software engineers. A computer software system based on cognitive learning theory was designed that was intended to be relevant to teaching, learning, curriculum development, and research in science education. The generic prototype software system was designed to serve three purposes: (1) to aid instructors and students of science in the construction of a meaningful knowledge base in a science discipline by means of concept mapping; (2) to serve as an intelligent, individualized, and interactive tutor for learning the concepts and conceptual relationships in a specified knowledge domain; and (3) to generate a database for subsequent analysis of, and research on, student misconceptions and how these might change through computer-based instruction. The database generated by the software program was designed to be used to guide subsequent construction, modification, or improvement of curricula. (TW)

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User Friendly Research: An Interactive Computer Software System Combining Teaching, Learning, Curriculum and Research*

By

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User Friendly Research:
An Interactive Computer Software System Combining Teaching, Learning, Curriculum and Research

OVERVIEW

In recent years, a substantial amount of research in science education has focused on students' knowledge structures, knowledge representations and misconceptions in science, and their potential impact on teaching, learning and curriculum development (Helm & Novak, 1983; Resnick, 1983; Champagne & Klopfer, 1984). Novak and Gowin (1984), guided by the cognitive learning theory of Ausubel et al. (1978) and Novak's (1977) theory of education, have recommended various tools and heuristics, such as concept mapping, to (1) identify the ways students represent and organize knowledge or conceptual relationships in a given knowledge domain, (2) help students to understand the conceptual and methodological structure of a discipline, and (3) aid students in organizing and learning new knowledge in meaningful ways by emphasizing the hierarchical relationship between concepts. One of the major theoretical assumptions upon which the use of concept mapping as a learning tool is based is that human memory systems are organized hierarchically, with abstract, inclusive concepts subsuming less abstract and less inclusive information. This assumption implies that if the content in a given discipline is sequenced and organized hierarchically, and thus in a way

compatible with the memory storage system of learners, the content will be more meaningful, easier to learn and easier to retrieve. There is evidence suggesting that concept mapping, or the organization of instructional materials into hierarchical conceptual schemes, can improve learning and retention, as well as performance on higher-order thinking and problem-solving tasks (Bower et al., 1969; Bower, 1970; Novak & Gowin, 1984).

The central purpose of our research was to develop a generic interactive computer software program based upon the theoretical perspectives on learning described above. The project was implemented through a collaborative effort between a team of science educators and a team of computer science software engineers at the University of Maine. The aim was to combine principles of cognitive learning theory, mastery learning (Block, 1971; Block & Burns, 1976) and computer software engineering technology in the design of an interactive computer software prototype that would teach students the content knowledge of a science domain through concept mapping and mastery learning strategies. It was intended that the software include provisions for:

(1) Instructor-researcher input of content knowledge (text/curriculum) and a concept map based on the content knowledge (the "master" concept map).

(2) Teaching students how to construct their own concept maps from the content (text/curriculum) presented, and

saving these maps on disk or some other storage device for subsequent analysis by the instructor-researcher.

(3) Enabling students to compare their concept map(s) with the master concept map constructed by the instructor or researcher.

(4) Directing students to laboratory or other hands-on activities based on concepts and principles presented in the program text and in the constructed concept maps.

(5) Presenting the student with a set of mastery, problem-solving application questions based on the concepts in the concept maps and in the laboratory activities.

(6) Saving students' responses to the mastery test items on disk or onto some other permanent storage system for subsequent retrieval and analysis by the instructor-researcher.

(7) Giving students the opportunity to improve their score on the mastery test after additional review of the program text, concept maps and the principles investigated in the laboratory/hands-on activities.

SOFTWARE SPECIFICS

A.) <u>Format</u>

The general format of the software program is as follows:

(I) Instructor Input Phase: The instructor (or researcher) inputs the content (text/curriculum) from a given knowledge domain, and then selects and highlights the key concepts in the text. The program generates a separate list of these concepts with menu-driven instructions and commands that permit the organization of the concepts into an individualized concept map. The program also has provisions for establishing and labeling connecting lines between concepts to form propositional relationships. The instructor's completed "master" concept map is saved as the standard.

(II) Tutorial Phase: The student accesses the program text/curriculum. The overall format is the same as described above for the Instructor Input Phase. Students follow a menu-driven program for designing a concept map which is automatically saved upon completion. The student is given one opportunity to revise his/her original map. After the initial attempt, the student is asked: "Would you like to see the text again to confirm or alter your map?" The student's revised concept map is automatically saved (as was his/her original map). The saved concept maps can be called up by the instructor-researcher to monitor the student's progress.

Next, the student is given the opportunity to compare and contrast his/her concept map(s) with the instructor's "master" map. The following message appears on the screen:

"This is your instructor's representation of the relationships among the major concepts from the text." The student will be asked to study the conceptual relationships in these maps and to note and be able to explain any differences between his/her map(s) and the instructor's "master" map.

Following this, the program refers the student to a series of relevant laboratory or other hands-on activities that illustrate and clarify the concepts in the program text (curriculum) and in the constructed concept maps. The purpose of these activities is to provide the student with concrete, hands-on learning experiences related to the concepts and principles being studied. The program generates the instructions and procedures to be followed for the laboratory activities. Students can request a hard copy computer print-out of these instructions immediately after viewing them on the monitor.

Students will be asked to analyze the activities using the "epistemological V" described by Novak and Gowin (1984). It is assumed that the concepts and principles the student learned by reading the program text and by constructing his/her concept map(s) will be the basis for the "left side of the V", and will help the student analyze the results of the activities in a meaningful way. Students' "V" analyses will be reviewed by the instructor/researcher who will provide the student with appropriate feedback.

(III) Evaluation Phase: Following the laboratory session(s) and the instructor's feedback, the student returns to the computer program where he/she will be presented with a series of focus or mastery application questions. These questions are in the form of problem solving scenarios asking the student to match a described problem situation with major concepts in the master concept map and laboratory activities. The mastery test serves two purposes: (1) to test the student's understanding of concept relationships, and (2) to test for an understanding of the details of specific concepts. All student responses are automatically saved for later analysis by the instructor-researcher. At the end of of the mastery test, the student is provided with his/her score. The student has the option of reviewing the text, concept maps and laboratory activities and may then re-take the mastery test in order to improve his/her score. The student's score on the second attempt at the mastery test is automatically saved for subesequent analysis by the instructor-researcher.

B.) The SUN Computer Workstation - Multiple Windows

The above concept-mapping program is currently being implemented on a SUN Workstation in the Computer Science Department at the University of Maine. The SUN station essentially is a high-powered personal computer with a large screen and a powerful processor that is capable of running more than one program at the same time. Other features of

this computer workstation include capabilities for: (1) high-resolution graphics, (2) fitting a large amount of text on the screen, and (3) projecting several "windows" on the screen at once. The cost of the basic workstation is about $3,500. Some computer engineers speculate that workstations of this kind will replace present-day personal computers within the next five years. IBM may manufacture a $1500 version of such a workstation shortly.

At its present stage of production, the concept mapping program on the SUN workstation has the following features:

(1) A large window where the concept maps are constructed by the instructor-researcher or student.
(2) A medium-sized window for input and editing of the text (curriculum) by the instructor/researcher.
(3) A small window containing a user-selected concept list from the text, as an interim step between the base text and the construction of the concept map in the large window.
(4) User control over scrolling in all three windows.
(5) The windows can be moved around the screen to more convenient positions and can be varied in size.
(6) Menu-driven, mouse-operated functions, including:
    (a) Text highlighting to select concepts.
    (b) "Select" function to transfer a highlighted concept from the text window to the concept list window.
    (c) "Add concept" function to transfer a concept from

the concept list window to the concept map window; a concept can be moved to any location in the concept map window.

(d) "Add relation" function to put connecting lines (arcs) between any two concepts.

(e) "Connecting word" function to add a word between two concepts that expresses the relationship between the concepts in the form of a proposition; a square or rectangular box is produced in the middle of the connecting line between two concepts; the user types in the connecting word to form a propositional statement.

DISCUSSION AND CONCLUSIONS

As of April, 1988, the software program described above was in the intitial stages of production. Efforts are under way to complete the project, although it is expected that completion will require at least one more year. At the same time, we are investigating possibilities for translating the SUN workstation program into a computer language that will permit interfacing the concept mapping program to more commonly used personal computers (e.g., Apple, Macintosh). One possibility is "Small Talk", a personal computer language that provides windowing capabilities. We may be able to port the SUN concept mapping program onto Small Talk

fairly easily, although greater limitations may be placed on graphics and resolution.

Upon its completion, the software is planned for instructional use in a Physical Science and Earth Science course offered for pre-service elementary and middle school teachers in the College of Education at the University of Maine. In the months following the implementation of the concept mapping program, we hope to collect data on its effectiveness as a teaching, learning and research tool. Initially, the text (curriculum) input will concentrate on a broad overview of the nature of Physical and Earth Science. As a database accumulates on students' major misconceptions and problem areas in these science domains, this computer-based curriculum can be modified and improved to better meet the needs of subsequent groups of students.

The generic software we have described could have broad applications across disciplines with regard to teaching, learning, curriculum development and research. Students' saved concept maps and responses to the mastery problem-solving application questions can provide the instructor-researcher with information about students' misconceptions and learning difficulties in a given content domain. This information can be used as a basis for individualized remedial instruction and for curriculum improvement. Our software prototype represents a "user-friendly" link (NARST, 1986 Keynote Address) between

practice and research, thus addressing a NARST research goal. With use, the software has the potential of becoming an evolving, research-based curriculum, capable of responding to the immediacy of learners' misconceptions in various content domains.

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APPENDIX I

An example of a section of Earth Science text (curriculum) and its corresponding concept map.

The Benefits of Concept Mapping

Concept maps are visual diagrams which facilitate understanding of relationships among concepts. There is a hierarchical representation of ideas with the most subsuming concepts placed at the top; arrows indicate direction of flow to the less abstract, more specific nouns below. Linking terms inserted between concepts add clarity. It is assumed that concept maps are compatible with the way information is stored and retrieved in human memory and therefore serve as useful learning tools.

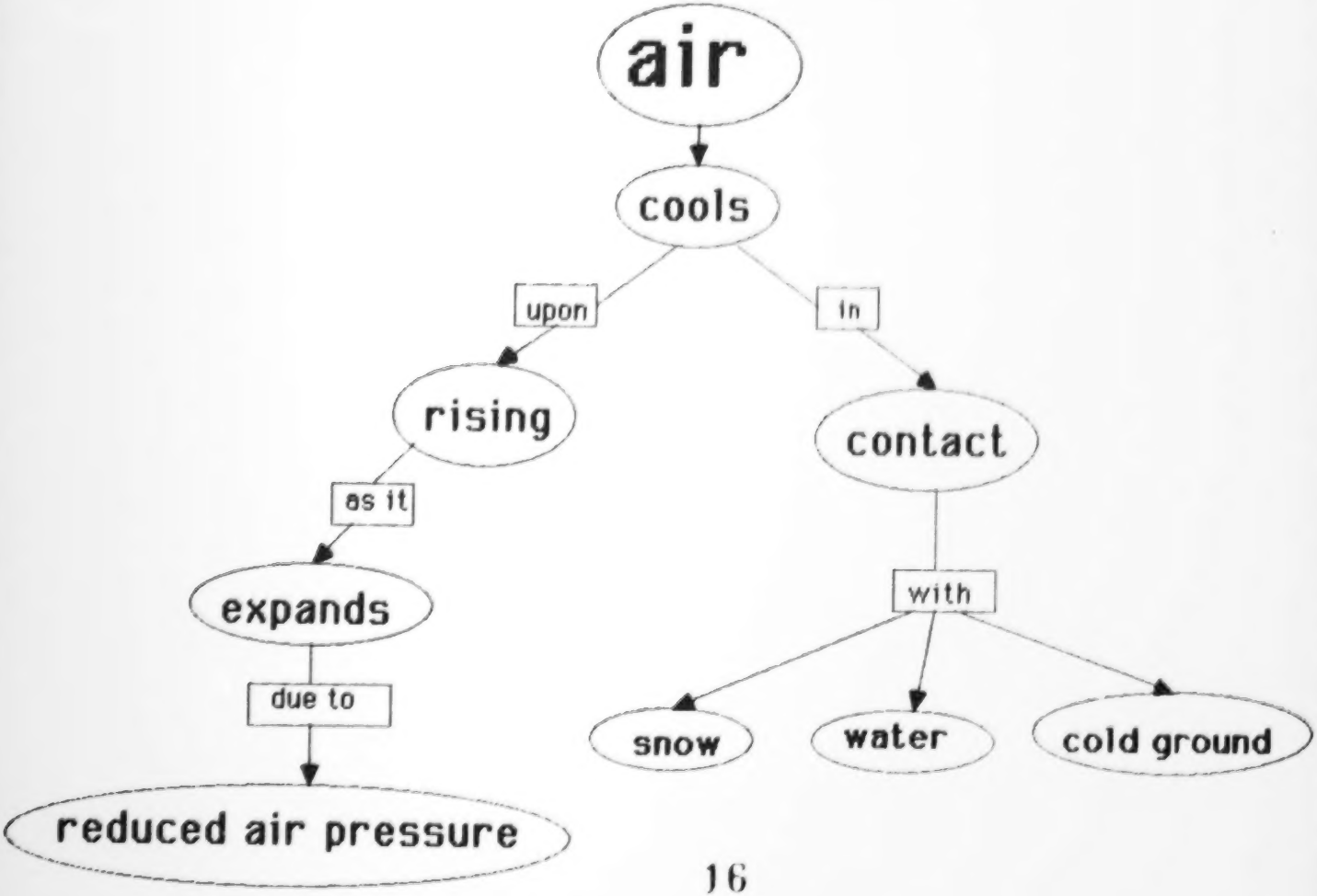
Sample Text - (Earth Science)

There are two important ways in which the air becomes cooled. One of these is by expansion; the other is by contact with cold surfaces.

Whenever air is forced to rise, due to updrafts from local solar heating or as a result of encountering mountain slopes, the temperature of the air falls. The air cools because the pressure drops as we move away from the strongest gravitational force at the center of the earth. The molecules are forced to separate, and with more space to roam freely, fewer molecular collisions occur. The term adiabatic refers to this process. It represents the relationship between pressure and volume whereby a gas or other fluid is compressed or expanded without a gain or loss of heat. The rate at which the temperature drops is called the adiabatic lapse rate; it is higher for unsaturated air. When moist air cools, the water vapor condenses releasing the latent heat of condensation, which warms the surrounding air. The latent heat of condensation is the energy absorbed and stored when a liquid converts to a gas in a phase change.

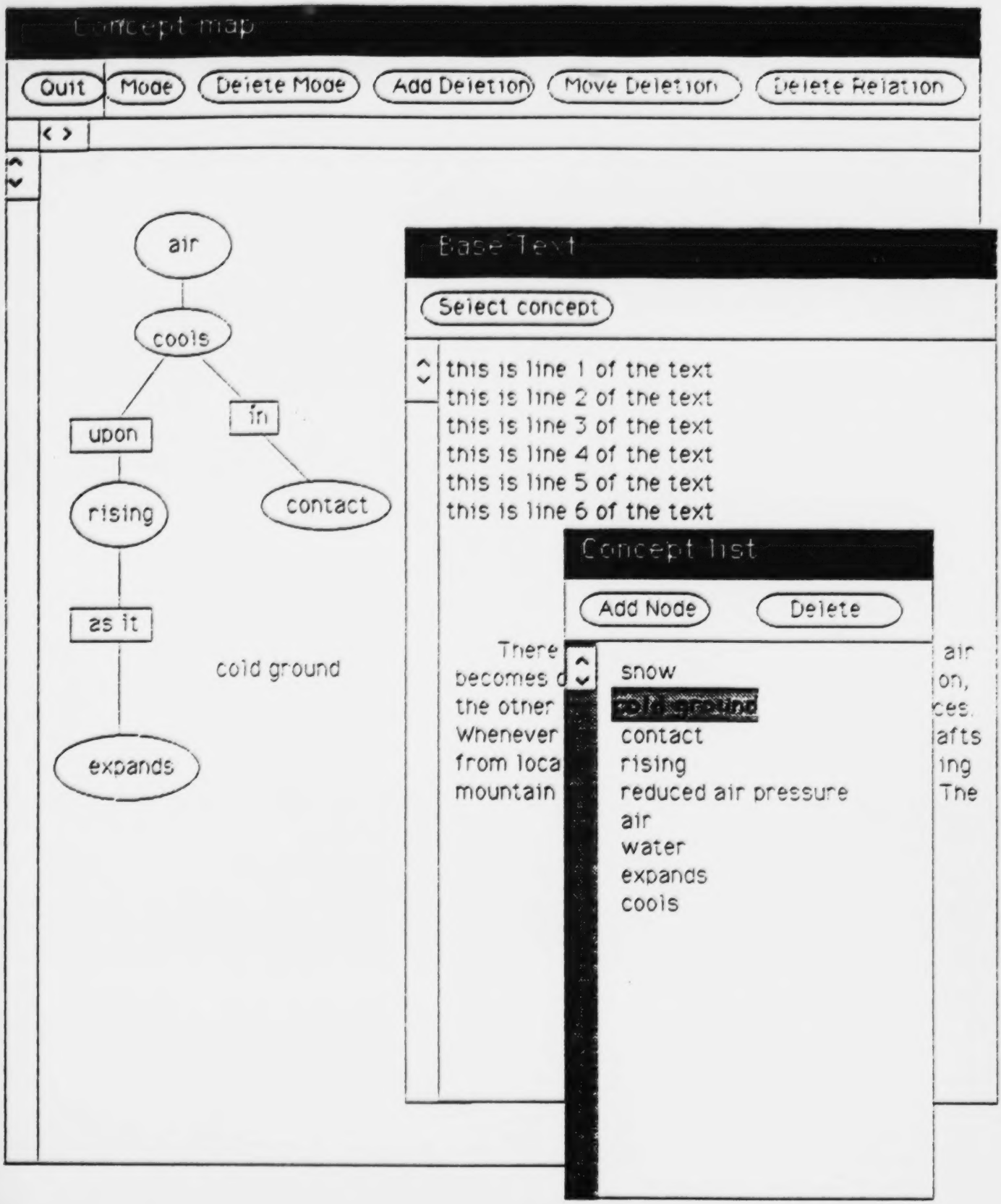
Cooling by contact occurs when the air near the ground comes in contact with snow-covered surfaces, cold water, or land that has absorbed little solar radiation recently. Cooling by contact is limited to a shallow layer of air because the cooler air is relatively heavy and clings close to the surface of the earth.

Corresponding Concept Map



APPENDIX II

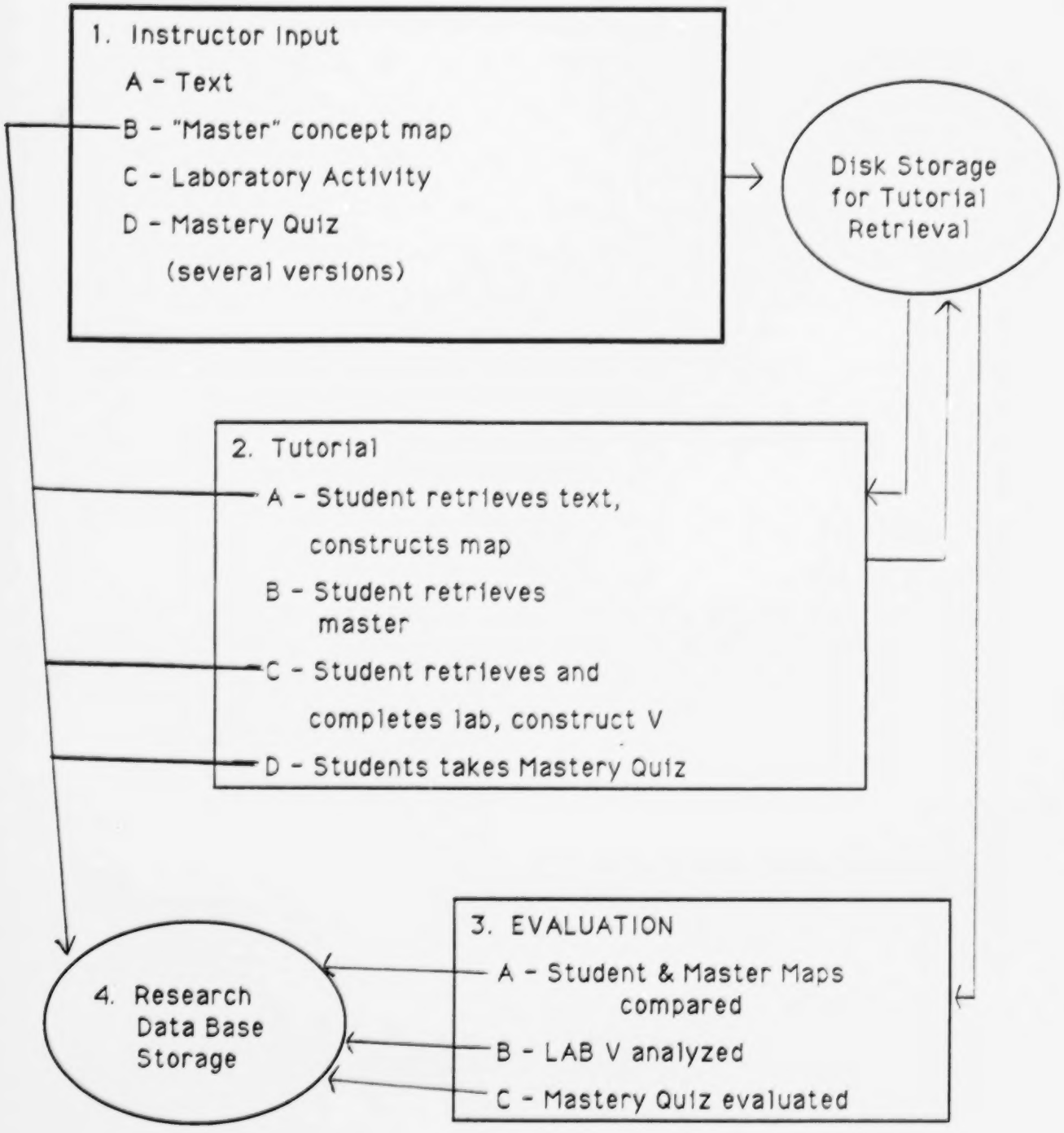
Computer monitor layout of windows, including text window, concept list window and concept map window.


Concept map
Quit
Mode
Delete Mode
Add Deletion
Move Deletion
Delete Relation
air
cools
upon
in
rising
contact
as it
cold ground
expands
Base Text
Select concept
this is line 1 of the text
this is line 2 of the text
this is line 3 of the text
this is line 4 of the text
this is line 5 of the text
this is line 6 of the text
Concept list
Add Node
Delete
snow
contact
rising
reduced air pressure
air
water
expands
cools

APPENDIX III

Schematic of phases of the software program.

PHASES OF SOFTWARE PROGRAM


1. Instructor Input
A - Text
B - "Master" concept map
C - Laboratory Activity
D - Mastery Quiz
(several versions)
Disk Storage for Tutorial Retrieval
2. Tutorial
A - Student retrieves text, constructs map
B - Student retrieves master
C - Student retrieves and completes lab, construct V
D - Students takes Mastery Quiz
3. EVALUATION
A - Student & Master Maps compared
B - LAB V analyzed
C - Mastery Quiz evaluated
4. Research Data Base Storage